Description

Apparatus and its parts for the electrodeposition of shaped dental parts

[0001] The invention relates to an apparatus and its important parts for electrodeposition, in particular for the electrodeposition of shaped dental parts, such as skeletons for crowns, inlays, bridges and the like, in accordance with the preamble of claim 1.

[0002] Electrodeposition, i.e. deposition under a flow of current, of metallic layers has already long been known. If this process is used to form shaped parts i.e. inherently stable bodies, it can be referred to as galvanoforming.

[0003] The use of galvanoforming in dental technology dates back to the start of the 1960s when Rogers and Armstrong produced inlays and onlays by electrodeposition. The at that stage still cyanide-based gold baths have nowadays given way to various gold baths which are not cyanide-based, such as for example the sulfite-based gold bath of the Applicant (EP 0 360 848).

[0004] Gold layers produced by electrodeposition have a significantly higher hardness than cast gold layers, at between 60-80 HV or between 100-130 HV, depending on the electrolyte composition. These electrodeposited gold layers are generally free of voids, inhomogeneities and impurities, which are inevitable when casting. Nevertheless, there may be disruptions to deposition caused by unclean working conditions and impurities entrained as a result or as a result of manufacturer-related appliance-specific process fluctuations. These disruptions to deposition manifest themselves, for example by the incorporation of impurities in the

electrodeposited material, the formation of buds or individual layers or holes in the layer. In the most unfavorable circumstances, disruptions of this nature can lead to loss of stability during firing and may therefore make the layers/shaped bodies obtained unsuitable for further dental processing. The problem when producing tooth restorations/shaped dental parts by electrodeposition lies in the in some cases complicated geometric shapes and the special deposition properties which are required. For stability and processing reasons, a uniformly homogeneous layer structure and also a layer thickness distribution that is as uniform as possible are desirable. The current-controlled electrodeposits, as are formed, for example, in the Applicant's AGC® appliances, have a considerably higher reliability and give reproducibly good properties.

[0005] For a number of years, various appliances have been commercially available on the dental market and are utilized in dental technology laboratories for producing tooth restorations or skeletons by electrodeposition. In this context, the term skeletons is to be understood as meaning the metallic base structures, such as crown caps or bridge caps, which are subsequently veneered, for example with ceramic, by the dental technician and then fired in order to form the final tooth replacement. For various reasons, in particular for biological compatibility for the patient, these skeletons are made from fine gold. The appliances mentioned are what are known as small electrodeposition appliances which, unlike industrial-scale electrodeposition installations, do not operate continuously but rather work discontinuously. Depending on the type and size of appliance, the process times are generally a few hours, for example 1 to 16 hours. These appliances can generally be placed and operated on a simple workbench, generally with a usable volume of electrolyte of approximately one liter or less, and a capacity of just a few tooth restorations, e.g. crown caps, which can be produced in a process therein.

[0006] Users of electrodeposition appliances of this type are generally people working in a dental technician's laboratory, for example dental

technicians, i.e. staff skilled in electrodeposition but without special training. Consequently, it is important that electrodeposition appliances of this type can be operated easily and without risk, specifically with regard to the quality of the tooth restorations produced therein and with regard to potential harm to the operator's health. Consequently, manufacturers of electrodeposition devices of this type endeavor to offer appliances which are as user-friendly and process-reliable as possible. Examples which can be mentioned in this context include the AGC® range of appliances produced by the Applicant, covering, for example, capacities of from 1 to 16 objects which can be electrodeposited simultaneously and process times of from 1 to 16 hours.

[0007] The contact-connection also needs to be considered in connection with achieving maximum user friendliness and process reliability. In the "electrodeposition appliance" there is an electrolyte (e.g. the AGC® gold bath produced by the Applicant), an anode and (at least) one duplicate model, provided with a layer of conductive silver, of a tooth or the mouth situation, which is connected as cathode. The duplicate model is connected to the current/voltage source in the appliance via a holding rod/wire, which generally at the same time functions as an electrical contact. This holding rod may be a stainless steel rod or, for example, a copper/titanium rod and can be designed for single use or to be reusable. Since with this type of contact rods a certain part is always immersed in the electrolyte during the process, this part should be electrically insulated from the electrolyte, so that it is not also plated with gold. This is generally done by what is known as a shrink-fit tube made from plastic or suitable coatings.

[0008] The contact rods/holding rods are then connected to the current/voltage source in the appliance via a plug-connection contact (e.g. a socket), by a metallic clamp or by a pinch contact. The contact to the appliance also needs to have a long service life and, if it is located within the electroplating cell, should not be susceptible to corrosion. Corrosion products can contaminate the electrolyte and put the entire functioning of

the process at risk. The production of the contact, i.e. the fitting of the appliance with duplicate models and the electrical contact-connection, is in this case effected by the operator.

[0009] In this context, particular demands are imposed on the contact-connection method, in order on the one hand to ensure process reliability and on the other hand to keep handling as simple as possible. For example for process reliability, it is imperative that the electrical contact remains reproducible for a prolonged period of time, i.e. throughout the entire the entire process time.

[0010] One drawback of the abovementioned types of contacts is that contact resistances always occur and may be undefined and under certain circumstances prevent sufficient current from flowing to the duplicate model which is to be electroplated. In such situations, faults may arise during the electrodeposition, which manifest themselves by the electrodeposited gold skeleton being too thin and/or having a disrupted layer structure or in extremis by the electrodeposition process being prevented altogether. Moreover, the abovementioned contacts are in some cases difficult for the operator to handle, and the parts connected to it are difficult to adjust with respect to one another.

[0011] Consequently, the invention is based on the object of avoiding or substantially ruling out the problems with contact-connection which arise in the prior art. It should be simple for the parts or models which are to be electroplated to be connected to the current/voltage source, and this connection should be reliably maintained throughout the entire process time. Furthermore, it should also be possible for the electrical contact to be interrupted again in a simple way in order to enable new parts/models to be introduced into the electroplating appliance.

[0012] This object is achieved by the apparatus having the features of claim 1 and the important components thereof, namely the electrode

having the features of claim 12, the current/voltage source having the features of claim 19 and the head or cover part having the features of claim 22. Preferred embodiments of this apparatus or the corresponding parts are presented in the dependent claims 2 to 11, 13 to 18 and 20, 21, 23 and 24. The wording of all the claims is hereby incorporated by reference in the content of the present description.

[0013] The apparatus according to the invention has at least one current/voltage source and electrodes which can be arranged in a vessel that can be filled with an electrolyte. To produce the electrical contact for the electrodeposition, at least one magnetic connecting means is provided between at least one electrode and the current/voltage source. In this context, the core concept of the invention is based on providing a magnetic contact-connection for producing the electrical contact between the electrode and the current/voltage source. The magnetic bonding force of two magnetic metal parts which are under electric voltage causes an electric circuit to be closed by the corresponding contact between these parts.

[0014] It will be clear from the statements made thus far that the magnetic connecting means which is provided in accordance with the invention is preferably of two-part design. In this case, a two-part design of this type may comprise a magnet as the first part and a second part made from a magnetizable metal. In a particularly preferred embodiment, the two-part magnetic connecting means comprises two magnets which produce the required contact by their mutual attraction. A particularly good holding force and minimal contact resistances are achieved if two magnets are used.

[0015] The abovementioned magnets are preferably what are known as permanent magnets, as are known from the prior art. These provide the required holding force at the magnetizable metal or against one another without the need for further auxiliary means to be used. Furthermore, the magnets used are preferably circular in cross section. Magnets of this type

can be described as round magnets.

[0016] In a refinement, in the apparatus according to the invention, a magnet is assigned to the current/voltage source. If the invention is realized in conjunction with the electroplating appliances mentioned in the introduction, appliances of this type often have what is known as a head or cover part which, when carrying out the electrodeposition, is arranged above the vessel accommodating the electrolyte. In embodiments of this type, the magnet assigned to the current/voltage source is preferably arranged on this head or cover part. In this way, it is then particularly easy to produce the contact with the electrodes. In said embodiments, a sleeve which accommodates the magnet is then provided in particular at the current/voltage source, preferably at the head or cover part. A particularly preferred embodiment of this type is explained in more detail below in conjunction with the drawing.

[0017] In further preferred embodiments, a magnet is assigned to the electrode or part of the electrode. As mentioned in the introduction, the electrodes are expediently rod-like components, which can be referred to as contact rods/holding rods. Accordingly, in these embodiments, the magnet is preferably arranged on these rod-like components. Such electrodes, in particular rods, preferably have a sleeve-like receptacle, into which the magnet is introduced. This will likewise be explained in more detail in conjunction with the drawing.

[0018] As will be clear from the description given thus far, the invention also encompasses a novel electrode for electrodeposition, in particular for the electrodeposition of shaped dental parts. According to the invention, this electrode is configured in such a way that it has at least one magnetic connecting means, in particular at least one part of a two-part magnetic connecting means. This electrode is preferably in the form of a rod, as fundamentally corresponds to the shape of the contact rods/holding rods which have been disclosed hitherto.

[0019] According to the invention, in the novel electrode, the magnetic connecting means or one part of it is provided at one end of the electrode. This is usually the end which, during the electrodeposition after production of the electrical contact, is assigned to the current/voltage source.

[0020] The magnetic connecting means may in this case be a magnetizable metal, which then interacts with a magnet assigned to the current/voltage source. However, the magnetic connecting means at the electrode is preferably a magnet, as has already been described in more detail above. A magnet of this type is preferably a permanent magnet. Magnets which are round in cross section (round magnets) are preferred.

[0021] In other preferred embodiments of the electrode according to the invention, the magnet is located in a sleeve-like receptacle at one end of the electrode (which is preferably of rod-like design). In order also to protect the magnet in this receptacle from corrosion, this receptacle can preferably be closed off by a cover part. This cover part is preferably of flat design. In this case, the top side of the cover forms the contact surface which interacts with the other part of the magnetic connecting means assigned to the current/voltage source.

[0022] The electrode itself can in principle be composed of any conductive material. However, it is preferable for the electrode and also any cover part which is present for closing the receptacle accommodating the magnet to be made from stainless steel. This material provides good protection against corrosion. If appropriate, the entire outer surface of the electrode, or preferably at least the top side of a cover part, which forms the contact surface, may be coated with another metal. A metal coating of this type can be used to further increase the corrosion resistance or the electrical conductivity. In this context, particular mention should be made of coatings made from gold or gold alloys, which can preferably be deposited by electroplating on the electrode or only on the cover part.

[0023] At its "lower" end, which during the electrodeposition carries the parts/models to be coated, the electrode according to the invention preferably has a smaller cross section than at its "upper" end, i.e. the end facing the current/voltage source or the head or cover part. It is preferable for the electrode to narrow or taper to a point at its "lower" end. It is in this way easier for the parts/models which are to be coated to be secured to the electrode, which simultaneously serves as a holding rod.

[0024] Finally, it should also be mentioned that the electrode may be provided on its outer surface with an electrically nonconductive coating, in particular with a plastic coating. This prevents electrodeposition of metal there and/or corrosive attack and damage to the electrode. It is preferable for the "lower" end of the electrode to be devoid of a coating of this type, in order to ensure simple contact-connection of the electrode to the parts/models that are to be coated.

[0025] As a further novel component, the invention comprises a current/voltage source and a head or cover part (as mentioned above) for electrodeposition, in particular for the electrodeposition of shaped dental parts. These components are likewise characterized in that they have at least one magnetic connecting means, in particular at least one part of a two-part magnetic connecting means. This may be a magnetizable metal or preferably a magnet. In this case too, particular mention should be made of permanent magnets. The magnets are preferably round in cross section (round magnets).

[0026] In these two novel components too, the magnet is preferably located in a sleeve-like receptacle. To protect against corrosion, this receptacle is preferably provided with a cover part. In this respect, reference may be made to the more extensive description given in connection with the electrode according to the invention. In this case too, the contact surface is then formed by the top side of the cover part.

[0027] Finally, the core concept of the invention can also be formulated as the use of at least one magnetic connecting means to produce the electrical contact between at least one electrode and a current/voltage source during the electrodeposition.

[0028] This electrodeposition is preferably electrodeposition used for the production of shaped dental parts, such as skeletons for crowns, inlays, bridges and the like.

[0029] The apparatus according to the invention or the components according to the invention of this apparatus have a number of advantages over those having the contact-connections which have been disclosed hitherto.

[1030] For example, in the invention, the required electrical contact is produced by a targeted magnetic force. This is sufficiently strong for this contact to be maintained throughout the entire time during which the electrodeposition is being carried out. This advantage manifests itself particularly clearly if the abovementioned preferred embodiments with two interacting parts of the magnetic connecting means, in particular the two abovementioned magnets, are used. On account of the targeted magnetic force, the two interacting parts are inevitably drawn into the correct position with respect to one another, so that the two parts, in particular the two magnets, lie congruently above one another. This ensures that there is always a defined contact surface and a poor electrodeposition result caused by undefined contact resistances is virtually ruled out.

[0031] A further advantage of the invention which should be mentioned is that the electrical contact-connection can be produced quickly and easily by the operator. For example, the electrode/contact rod is easy to replace, which significantly increases the working efficiency for the operator. Furthermore, there is no need for any maintenance whatsoever to be

carried out on the components, since, for example, contamination of the contact surfaces is substantially ruled out. Should cleaning prove to be necessary from time to time, this cleaning can easily be effected by simply wiping the components.

[0032] Yet another advantage of the embodiments according to the invention manifests itself if the process temperatures of standard electrodeposition, in particular in the dental sector, are applied. Process temperatures of this type are generally in the range between 50°C and 70°C, and are usually approx. 65°C. The result of this is that condensation products from the electrolyte usually collect in the upper part of the vessel or the electroplating cell. On account of their chemical composition, condensation products of this type can lead to corrosion at the parts which produce the electrical contact. The products which are produced by the corrosion can then in turn enter the electrolyte and contaminate the latter. Impurities of this type can then be included in the electrodeposition, for example can be deposited together with the gold, and in this way have a significant adverse effect on the quality of the electrodeposited shaped parts, in particular the tooth replacement skeletons. The contact-connection which is effected in accordance with the invention can rule this out with virtual certainty. This applies in particular to the embodiments in which the magnets are located in a sleeve-like component which is securely closed off by a cover part.

[0033] The advantages of the invention manifest themselves particularly clearly in particular in the latter embodiments with a type of cladding structure for the magnets used to produce the electrical contact. In embodiments of this type, the magnet is completely protected by this cladding structure. Accordingly, the material used for structures of this type is preferably a corrosion-resistant stainless steel. This rules out corrosion to the electrical contact-connection. If a layer of gold is additionally applied to the stainless steel electrode/stainless steel rod, at least at the contact surfaces, such as for example the cover part, on the one hand this

corrosion resistance is increased still further, and on the other hand an excellent electrical conductivity is achieved. Therefore, with these embodiments, in combination with the other design features, an excellent, permanent and reproducible electrical contact is created at the contact locations between electrode/holding rod and current/voltage source or head or cover part.

[0034] Finally, the electrode according to the invention or the holding/contact rod according to the invention is permanently reusable. This applies in particular if it is additionally coated at its surface with a protective layer, preferably a nonconductive protective layer, such as for example a plastic.

[0035] These and other features of the invention will emerge from the examples and drawings described below in combination with the claims. In this context, the individual features can be implemented on their own or in combination with one another. In the drawings:

Fig. 1 shows a diagrammatic cross-sectional illustration of an electrode according to the invention or a holding/contact rod according to invention with inserted magnet, and

Fig. 2 shows a diagrammatic sectional view of a component according to the invention with inserted magnet, which can be assigned to a current/voltage source or a head or cover part of an apparatus according to the invention.

Examples

[0036] An electroplating appliance of type AGC® Speed, produced by the Applicant, is modified in accordance with the invention. The starting point for this is the single-cell version of this appliance, which is not illustrated in more detail in the figures. The appliance substantially comprises a housing,

which accommodates the current/voltage source and the control unit. Moreover, the appliance has an electrolyte container with a head or cover part, to which the anode and the cathode, which is provided with the part/model that is to be coated by electrodeposition, are secured. In the case of the AGC® Speed appliance produced by the Applicant the entire electrolyte container with head or cover part can be removed from the appliance. This simplifies the introduction of the parts/models which are to be coated into the electrolyte container and protects the remaining components of the appliance from contamination, for example by the electrolyte.

[0037] In the previous design of the AGC® Speed appliance produced by the Applicant, plug-connection contacts were used for securing/contact-connecting the anode, which is generally designed as a ring anode, and in particular the holding/contact rod, which is connected as a cathode. In this context, the upper ends, which are of rod-like design, of these electrodes were introduced into corresponding receptacles in the head or cover part and, for example, latched in place. However, this inherently reliable contact-connection often did not allow rapid exchange. Moreover, the contact surfaces had to be protected against corrosion from vapors rising up from the electrolyte in a relatively complex way.

[0038] The two components illustrated in Figures 1 and 2 are used to modify the described appliance produced by the Applicant in accordance with the invention.

[0039] In this context, Figure 1 shows an electrode 1 according to the invention in the form of a holding or contact rod. This electrode 1 is made from stainless steel and has a smaller cross-sectional area at one end 2 than at the other end 3. The end 2 is in this case designed in the form of a point which serves to secure the electrode to a part or model (not shown in Figure 1) which is to be coated by electrodeposition. This is explained in more detail below.

[0040] At the other end 3 there is a sleeve-like receptacle/recess 4, into which a magnet 5 has been introduced. This magnet 5 is a permanent magnet with a round cross-sectional area, i.e. what is known as a round magnet. To protect this magnet 5 from corrosion, a cover part 6, which is likewise made from stainless steel and closes off the receptacle 4 in a sealed manner, is present on the electrode 1. Consequently, the design 3 of the electrode 1 means that the magnet 5 is completely enclosed.

[0041] According to the invention, the surface 7 which is present on the outer side of the cover part 6 forms the contact surface, via which the magnet 5, as one part of the two-part magnetic connecting means can interact with a second part. To optimize the electrical contact produced by the magnetic force, the surface 7 or if appropriate the entire outer surface of the electrode 1 may be gold-plated. This is not shown in more detail in Figure 1. Equally, it is possible for the outer surfaces of the electrode 1, with the exception of the surface 7 which serves as a contact surface, to be provided with a plastic coating. This then prevents undesirable electrodeposition from taking place on the electrode itself. If the plastic coating is not present, this deposition is prevented by the operator by other measures, for example by surrounding the electrode 1 with a shrink-fit tube.

[0042] Figure 2 shows a sleeve-like component 11 which is round in cross section and is likewise made from stainless steel. This component 11 forms the mating piece for the electrode 1 from Figure 1 which serves as a holding/contact rod. The component 11 may, for example, be introduced into the abovementioned head or cover part of the AGC® Speed appliance produced by the Applicant, or may be assigned to the current/voltage source in a different way in the case of a different design of an electrodeposition appliance.

[0043] At one end 12, the component 11 has a receptacle/recess 13, into which a magnet 14 has been introduced. In this case too, the magnet 14 is

a permanent magnet which is round in cross section, i.e. a round magnet. The receptacle 13 with the round magnet 14 is closed off in a sealed manner by a cover part 15, which likewise consists of stainless steel. This once again prevents the magnet 14 from being corroded by vapors which rise up from the electrolyte.

[0044] In the case of the component 11, the outer surface 16 which is present at the cover part 15 represents the contact surface for the magnet 14 to interact with the other part of the two-part magnetic connecting means. In this case too, the surface 16, and if appropriate the entire outer surface of the component 11, may be gold-plated. Corresponding plastic coatings (apart from at the surface 16) are also possible.

[0045] If the surface 7 of the electrode 1 is now moved toward the surface 16 of the component 11 (with the magnets 5 and 14 which have been introduced correctly oriented), these two surfaces are attracted by the magnetic force and correctly positioned with respect to one another. At the same time, the electrical contact required for electrodeposition is produced. The electric current can then, for example, flow across the component 11 with the surface 16 into the surface 7 of the electrode 1 and therefore also to a model of a tooth restoration secured to its end 2. Of course, an electrical contact can also be produced in the same way for an electrode connected as anode. An anode of this type will usually simply be a metal rod.

[0046] Tooth restorations are produced by galvanoforming using an AGC® Speed appliance produced by the Applicant which has been modified using the components shown in Figures 1 and 2. In this case, the component 11 (cf. Figure 2) has been introduced into the head or cover part of the appliance, and the electrode 1 (cf. Figure 1) is used as holding/contact rod for the tooth restoration or the model.

[0047] In the two experiments presented below, the starting material is in

one case a plaster stump, which is rendered conductive in the usual way using conductive silver. In the other case, the starting point is a metallic primary crown, which to take account of the cement which subsequently joins primary crown to secondary crown, is likewise coated with conductive silver (double crown technique). The electrolyte used is a sulfite-based gold bath produced by the Applicant. However, the composition of the bath is not critical to the advantages according to the invention taking effect.

[0048] The preparation for and execution of the electrodeposition is summarized in the table below. Both examples produce perfect shaped parts made from fine gold with layer thicknesses of 300 µm. This demonstrates that the "magnet contact-connection" according to the invention leads to the high-quality shaped parts required in dental technology. If the advantages which are achieved compared to previous contact-connections, as have already been mentioned in the introduction to the description, are taken into account, the modification to the appliance in accordance with the invention represents real progress.

Example		1	2
Stump material	**Type**	Plaster stump; conductive silver	Metallic primary crown; conductive silver
Magnet contact-connection	**Contact in the appliance**	Magnet in stainless steel sleeve	Magnet in stainless steel sleeve; gold-plated
	Contact rod	Magnet contact rod, stainless steel sleeve; shrink-fit tube	Magnet contact rod, stainless steel sleeve; gold-plated; shrink-fit tube
	Electrical contact	Magnet/stainless steel/stainless steel/magnet	Magnet/stainless steel/gold/gold/ stainless steel/magnet
Electro-deposition parameters	**Time**	1.5 h	4 h
	Mean current density	2.5 A/dm^2	2 A/dm^2
	Form of current	Pulsed current	Pulsed current
	Temperature	65°C	65°C
Electro-deposition appliance	**Type**	AGC Speed	AGC Speed
Description		A 1.2 mm thick hole is drilled into the plaster stump and the thin, uninsulated side of the magnet contact rod is bonded into it using	The primary crown is filled with plastic and the thin uninsulated side of the magnet contact rod is embedded in the plastic. The surface

		quick-setting adhesive. The surface which is to be electroplated is covered with conductive silver and the surface is connected to the rod. The part which has been prepared in this way is placed on the mating magnetic contact in the mounting head and the latter is introduced into the electrodepo-sition cell. The electrodeposition cell is introduced into the appliance and the process is started.	which is to be electroplated is covered with conductive silver and the surface is connected to the rod. The part which has been prepared in this way is placed onto the mating magnetic contact in the mounting head and the latter is introduced into the electrodeposition cell. The electrodeposition cell is introduced into the appliance and the process is started.
	Result	The electrodeposited crown satisfies all the quality requirements. Handling is extremely simple, safe and fast.	The electrodeposited crown satisfies all the quality requirements. Handling is extremely simple, safe and fast.